No. 85250

HARTL OPTICAL DISC

(Trade Mark Reg. U. S. Pat. Off.)

Designed by Professor Hans Hartl, Reichenberg, Czecho--Slovakia

This apparatus is designed to illustrate in a simple and perfect way the fundamental laws of Optics. The only necessary accessory is a strong source of light; such as the sunlight, or a beam of parallel rays from an arc such as our No. F6402. The sunlight may be used either directly as it falls into the room through a partly shaded window, or if there is no direct sunlight it may be reflected into it by the use of a suitably placed simple mirror. It is not necessary nor desirable to use a darkened room. If the light in the room is partly reduced by lowering the shades, the paths of the light rays upon the graduated disc, lenses and mirrors, can be seen by the entire class.

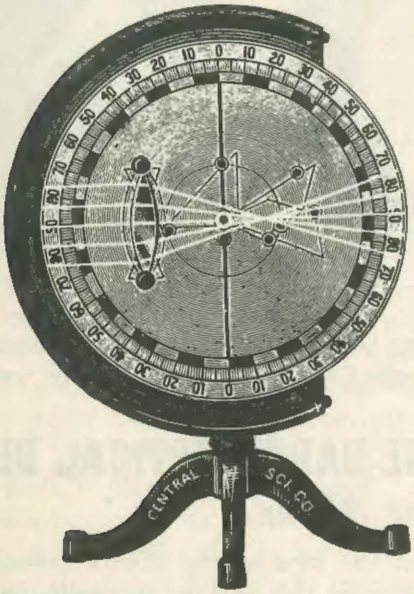

Fig. A

The apparatus consists of a graduated scale clearly printed on a heavy aluminum disc (Fig. A), and a semi-circular sheet metal screen. These two parts turn independently upon the same horizontal axis, which is carried by a heavy tripod base. The disc is graduated in degrees and has two diameters marked upon it.

The optical parts (Fig. B), consist of a set of 4 concave and convex lenses, 2 prisms, a plane, a concave and a convex mirror; any one of which may be attached to the face of the disc by means of thumb screws. The lenses and prisms are whitened on one side so that the path of the light in the glass may be actually seen just as it is seen on the face of disc. The outlines of the lenses and mirrors are marked upon the disc so that they may be easily placed in the proper position for use These outlines are so placed that the necessary angles—such as the angles of incidence, reflection, refraction, etc—may be easily obtained from the graduated circle.

The semi-circular screen is so mounted as to remain fixed in any position and has a handle for adjustment. This screen has at its center a square opening over which slide two slotted plates, one with 3 and the other with 7 slits. These slits may be separately closed with a brass slider or covered with a colored screen.

The colored glass screens make it possible to easily trace each beam of light when two or more beams are passed through a lens or prism.

The Adjustment of the Optical Disc.

The disc is placed so that the beam of light strikes its edge. The semi-circular screen is then turned so that it is between the light and the disc. The light beam

should be large enough to cover at least three-fourths of the semi-circular screen. The entire apparatus should then be very slightly turned, so that the beam of light passing through the opening in the screen will trace out its paths upon the face of the disc. With the 3-slit plate in position and two of the slits closed, a single ray of light will cross the disc and by turning the semi-circular screen on its horizontal axis this ray of light may be moved parallel to itself and made to cross the disc at any desired point.

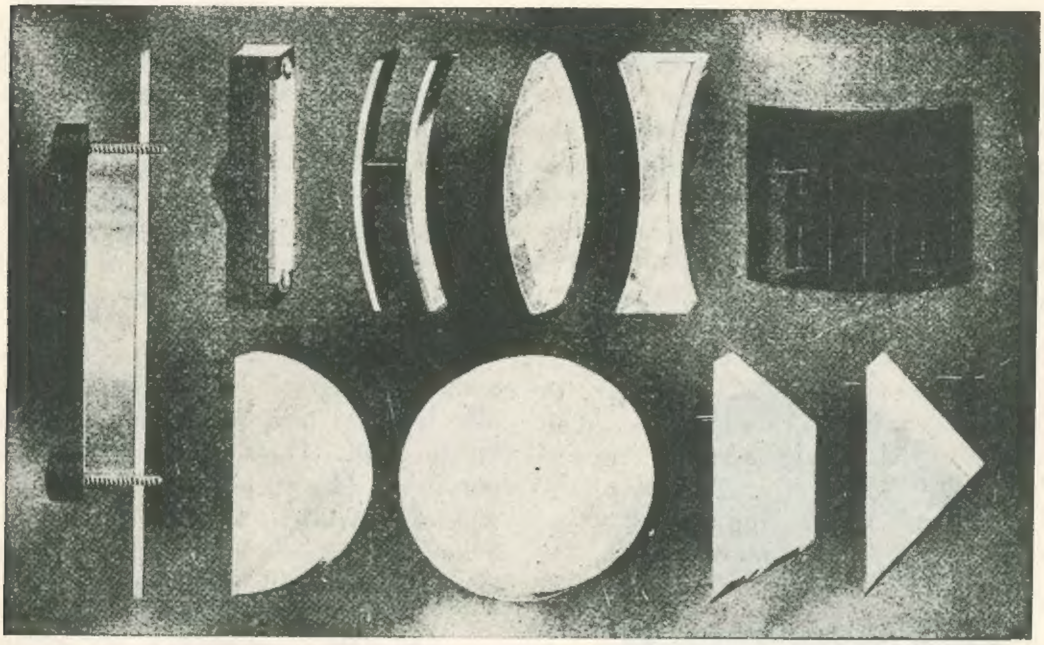

Fig. B

By leaving the screen stationary and rotating the disc, the angle of incidence of this ray, upon any lens or mirror fastened upon the face of the disc, may be varied at will.

SUGGESTED EXPERIMENTS FOR THE HARTL OPTICAL DISC

Reflection by a Plane Mirror.

Fasten the plane mirror to the disc so that the face of the mirror coincides exactly with the diameter, 90-90. The other diameter, 0-0, will be perpendicular to the mirror. Pass one ray of light through the screen; turn the screen on its horizontal axis until this ray strikes the mirror exactly at the center of the disc (Fig. No. 1, page 6) and if the mirror has been properly placed the angle of incidence and the angle of reflection will be equal. If they are not, the mirror should be adjusted until this is true. Leaving the screen stationary and turning the disc it will be easily seen that the law of reflection holds for *any* angle of incidence.

To Show that a Parallel Beam is Still a Parallel Beam After Reflection From a Plane Mirror.

To perform this experiment place the 7-slotted plate in the screen and arrange the apparatus as shown in Fig. C.

Reflection by a Concave and Convex Mirror.

Screw the concave mirror to the center of the disc, putting a thin piece of paper under the back edge to tip it slightly forward and turn the screen so that

the single light ray crosses the center of the disc. Rotate the disc until this ray is in the axis of the mirror and leaving the disc stationary and rotating the screen slightly backward or forward, the ray will be moved parallel to itself across the face of the mirror. The reflected ray will be seen always to pass through one point of the disc—the *Principal Focus.* Mark this point! (Fig. 3.) Find now the point on the axis of the mirror twice as far away from the mirror as the distance of the principal focus. This is the *center of curvature* of the mirror. All light passing through this point is reflected back upon itself, as can be shown by adjusting the screen and the disc so that a ray passes across this point and falls upon the mirror.

The same experiments may be performed with the convex mirror in place of the concave mirror. (Fig. 4.)

In place of one slit, the plate with seven slits may be placed in the screen and the focusing of parallel rays shown. (Fig. 5 and 6.) By removing the plates from the screen and using the full opening the *Caustic Curve* may be seen.

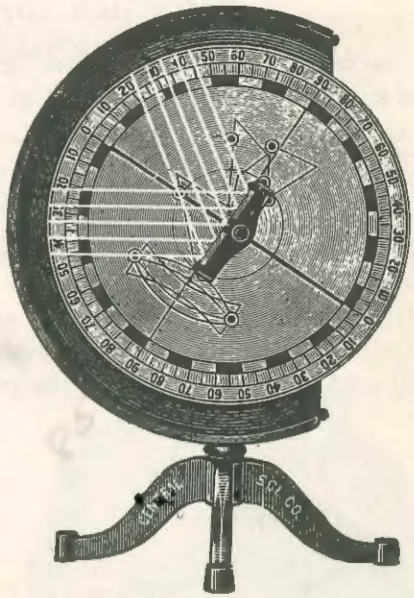

Fig. C

Refraction of Light.

Place the hemispherical glass plate upon the disc so that the straight edge coincides with the diameter, 90-90. Adjust the screen so that the ray falls upon the flat edge at the point where the 0-0 diameter touches it. Part of the ray will be reflected and if the angle of reflection is equal to the angle of incidence, the glass is properly adjusted. The rest of the ray will pass into the glass, be refracted and then pass out through the circular edge with its direction unchanged. (Fig. 7.)

The angles of incidence and refraction may be read off at once and the law of refraction verified. As an example the following experiment was performed: the angle of incidence was made successively 55^{0} and 31^{0}, the corresponding angle of refraction was observed to be 33^{0} and 20^{0}. These values give sin A: sin B to be 1.504 and 1.506.

By rotating the disc through 180^{0} the light may be sent through the glass in the opposite direction, so that the light passes from the glass to air and the angles of incidence and refraction are reversed. (Fig. 8.)

Vary the angle of incidence and the reflected ray will be seen to vary in intensity. When the angle of incidence reaches a certain value (about $41\frac{1}{2}^{0}$), all of the light will be reflected. (*Total Reflection,* Fig. 9.) The angle where *total* reflection begins (the Critical Angle) may be read off the graduated circle. By use of the single slit covered with a colored screen, the critical angle may be shown to be smaller for violet than for red light.

In view of the frequent application of the total reflecting prism (as in Perre's prism system and the modern binocular field glass) Prof. Hartl has designed a special prism to show its use.

Fig. D shows the arrangement of the apparatus. The fact that the rays

are inverted in position after reflection may be more strikingly shown by the use of two differently colored rays. (Perre's system.)

In turning the disc so that the ray falls perpendicular to one leg face of the right angle prism, only one reflection will be seen on the hypothenuse face. (Binocular.)

Refraction Through a Parallel Plate.

The fact that a parallel plate does not change the direction of the ray, may be shown by arranging the prism as in Fig. 10.

Refraction Through a Prism.

Place the trapezoidal glass plate on the disc so that either the 45° or 60° angle is bisected by the 90-90 diameter.

Use a colored ray in order to avoid the dispersion which would be present, if white light were used; let the ray fall upon the edge of the glass plate as shown in Fig. 11 and 12, so that half of the ray passes through the glass and the other half passes by the edge unchanged. The deflection of that part of the ray which passes through the glass may be read off at once upon the graduated circle. By using first the 45° angle and then the 60° angle it will be seen that the deviation increases when the angle of the prism is increased. Notice also that the prism angle is bisected by the 90-90 diameter and that the minimum deviation of the light ray occurs when the incident and the refracted ray form equal angles with this diameter; that is, the deviation increases when the disc is turned in either direction from this position.

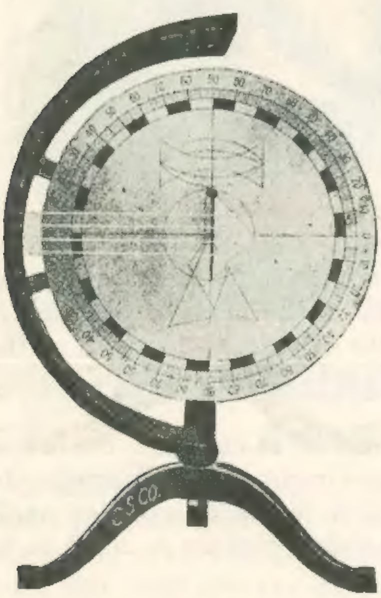

Fig. D.

Dispersion.

In order to show dispersion white light is used and the refracted beam may be received upon a white screen or the wall. If a brighter spectrum is desired the slotted plate may be removed from the screen and a prism held against the disc in front of the square opening of the screen.

Refraction Through Lenses.

Fasten the lens to the disc at right angles to the 90-90 diameter as indicated on the disc. Using a single ray of white light as in the case of the concave and convex mirror experiments, adjust the disc and the screen so that the ray passes through the center of the lens. (Fig. 15.) Notice that the direction of the ray is unchanged. All rays which pass through the optical center in this way are known as *Principal Rays.*. Turn the disc so that the 90-90 diameter (*the axis of the lens*) is parallel to the incident ray. Turn the screen about the horizontal

axis and note that the refracted ray turns about one point on the disc. This is the *Principal Focus* of the lens (Fig. 14). The location of the principal focus may also be shown by using the plate with seven slits (see Figs. 16 and 18), which shows the focusing of a beam of parallel rays. By turning the disc the action of the lens upon this beam when it is inclined to the axis of the lens may be studied. The *Caustic* for a lens may be most readily shown by using the square opening in the screen as shown by Fig. 17.

Theory of the Rainbow.

Fasten the circular glass plate, representing a drop of water, upon the center of the disc. Let a single ray fall nearly tangentially upon the upper edge of the glass plate. (Fig. 20.) This ray will enter the glass, be reflected at the farther edge and leave the plate again at the lower edge, being refracted both where it enters and leaves the glass. Hold a white card very obliquely in the emergent ray and notice that it is colored. This illustrates the formation of the *Primary Bow.* The loss of light by reflection where the ray enters the glass and by transmission where it is reflected explains the weakness of the light in the rainbow. By the use of a very bright beam striking the bottom of the glass plate nearly tangentially, the formation of the *Secondary Bow* may be shown.

Other Experiments.

The experiments described above are only a few of *many* which may be performed by means of the Hartl Optical Disc. A few other experiments which may be mentioned are: the passage of light through combinations of lenses (Fig. 19), the illustration of the principles involved in the Newtonian Telescope, the effect of a prism upon rays having a different angle of incidence to it, Fig. E, etc., etc.

Fig. E

Chart of Experiments Performed with the Hartl Optical Disc

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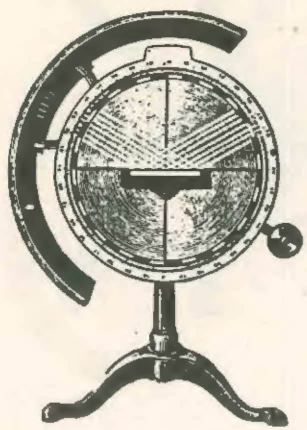

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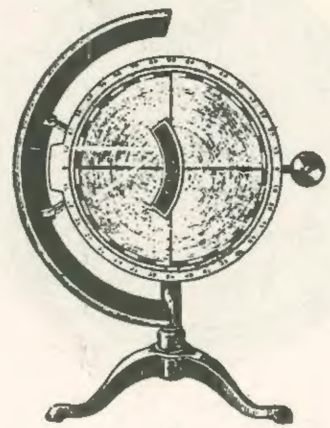

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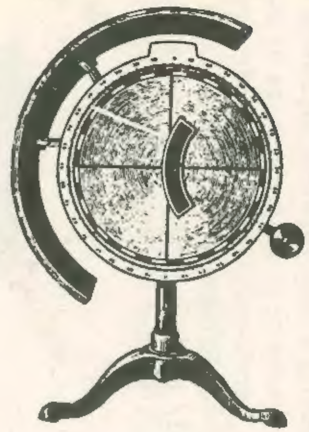

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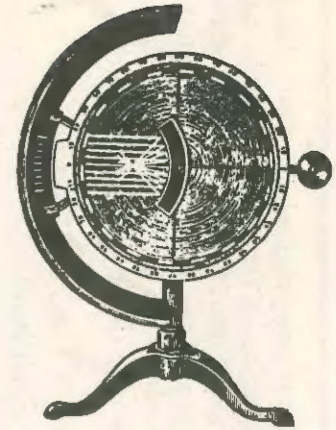

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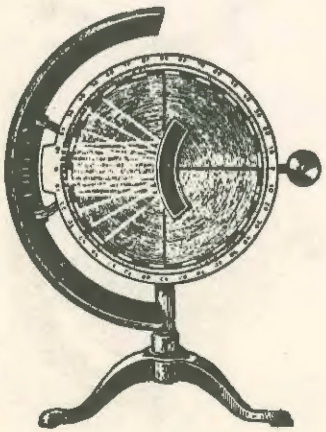

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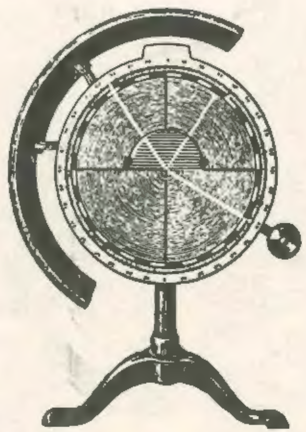

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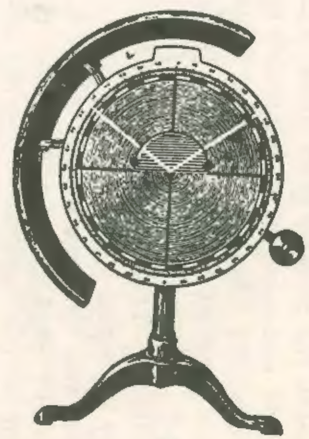

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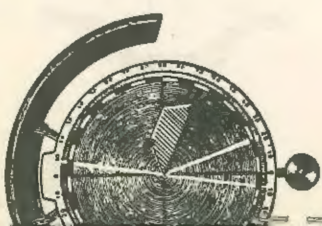

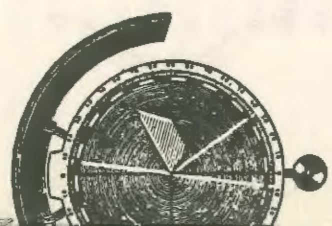

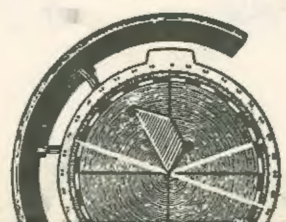

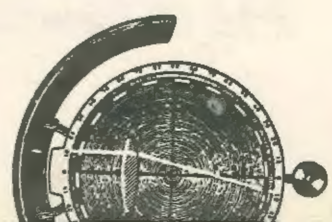

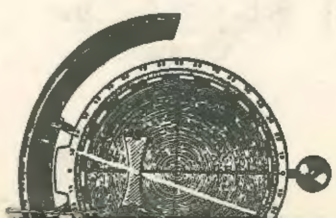

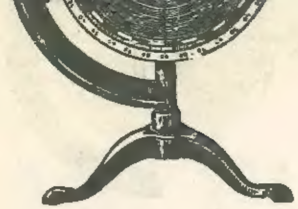

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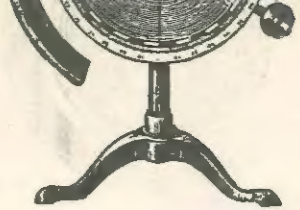

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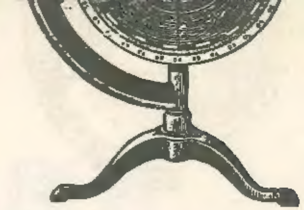

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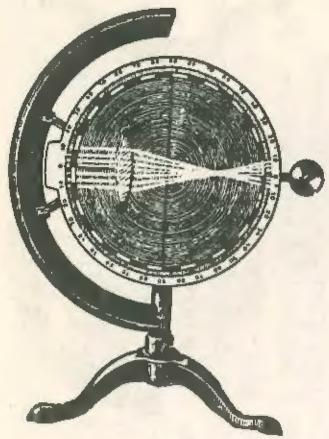

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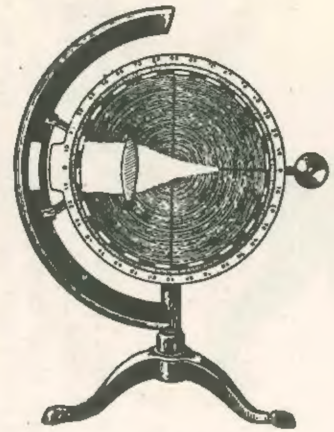

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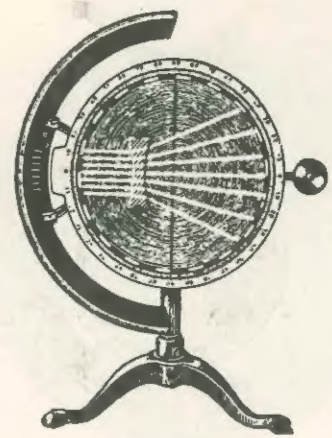

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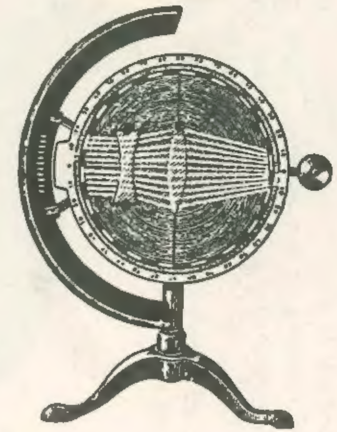

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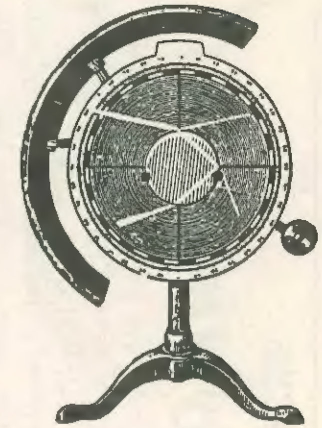

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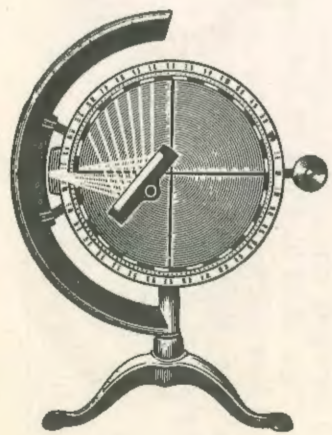

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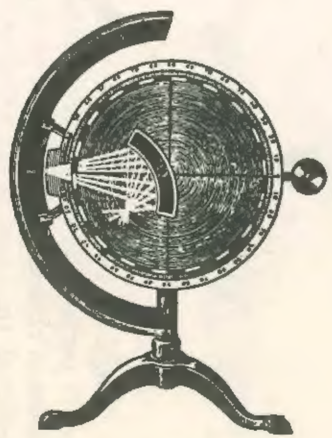

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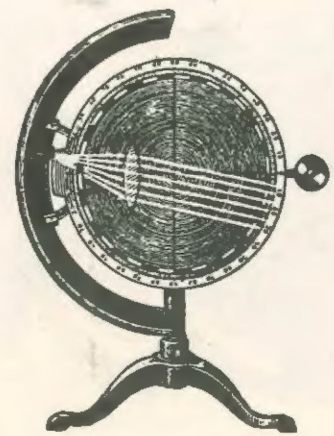

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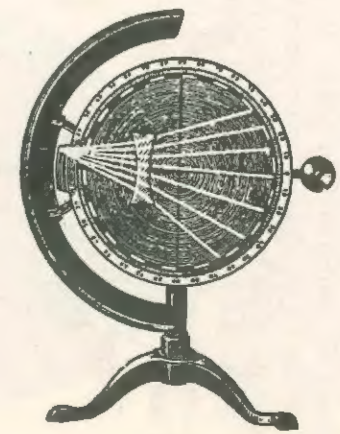

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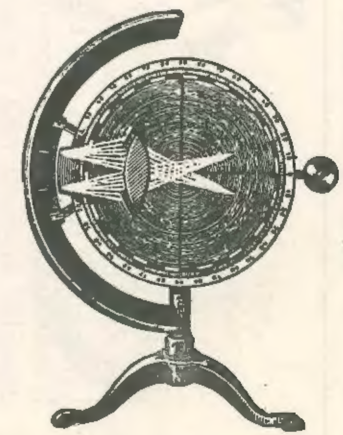

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No. 85285

Diverging Ray Attachment

In order to illustrate the action of lenses and mirrors upon diverging rays such as come from an ordinary object or source of light, Professor Hartl has designed a special attachment to be used with the Hartl Optical Disc. (Fig. F.)

It consists of a glass plate forming a system of parallel concave cylindrical lenses, and ·djustably mounted with a counterpoise, upon a separate base. This is placed between the screen and the source of light ordinarily used with the Optical Disc so that the center of its shadow coincides with the opening in the screen. Each cylindrical lens sends out a bundle of diverging rays; one ray from each lens will pass through the slit in the screen, thus forming a system of rays which appear to come from the slit as a source and cross the disc. The divergence of this bundle may be varied by varying the distance of the glass plate from the screen.

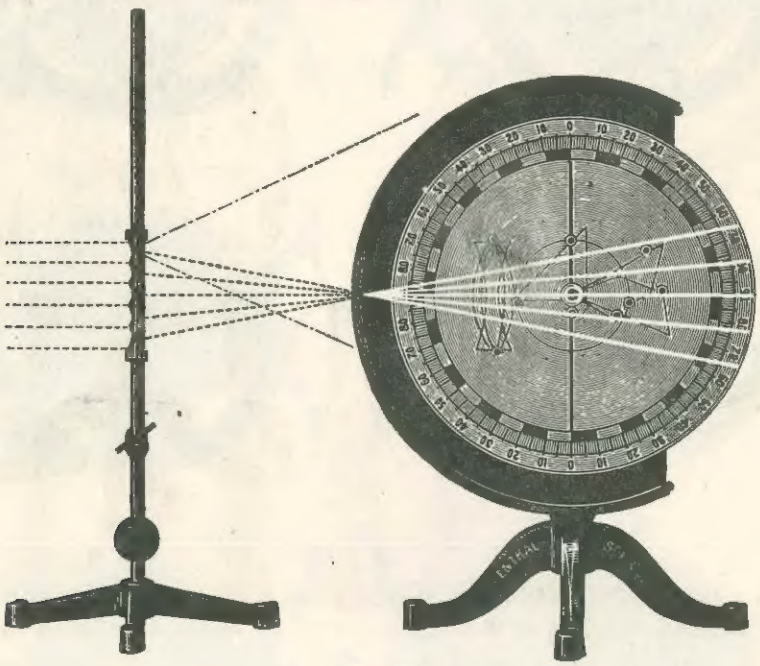

Fig. F

Since the light, of necessity, must be weaker, the room should be somewhat darkened in performing these experiments. By the use of two or more slits, two or more bundles of rays may be seen just as in the case of an extended light source. With these bundles all the experiments which were performed with parallel rays may be performed with diverging rays, and the action of optical instruments fully explained.

Figs. 21-24 illustrate experiments with a bundle of diverging rays. Fig. 25 illustrates how the principle of image formation may be shown. In order to get the best results one of the slits may be covered with a colored glass screen and the metal screen (diaphragm) should be placed over the edges of the lens.

By the use of the thick convex lens combined with one of the thin lenses, the fact that an extra lens makes the image either recede from or approach the first lens, is shown. This illustrates the action of eye-glasses. The thick lens acting as the eye lens and the thin lens as the eye-glass.

No. 85275

Refraction Tank

Refraction tank (Fig. G.) consists of a metal tank with crystal glass front. The glass covers a trifle more than a semi-circle, so that the water level may coincide with the 90-90 diameter, without spilling. The tank is attached to the face of the Hartl Optical Disc (Fig. H.) which may be rotated independently of the tank.

Fill the tank with water or other transparent liquid, to exactly coincide with the horizontal diameter (90-90). Place the apparatus in the sunlight and pass a ribbon of light through a single slit, striking the exact center of the tank. (Fig.H) If a direct beam cannot be thrown on the tank, a reflected beam can be obtained

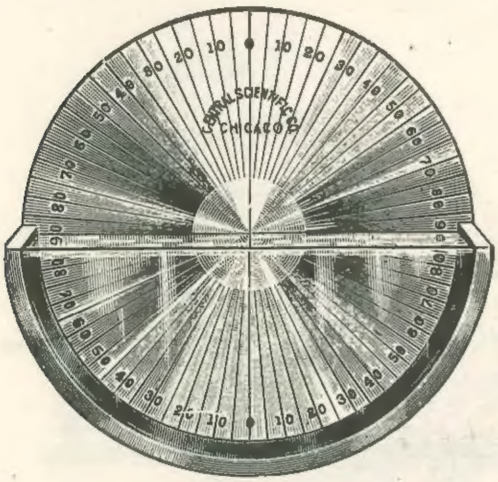

Fig. G

Fig. H

by using the plane mirror furnished with the Optical Disc. This mirror is clamped to the upper edge of the disc and may be placed to throw a beam of light from any angle.

Observe the angles of incidence and refraction. Refer to a standard table for the sines of these angles. Divide the sine of the angle of incidence by the sine of the angle of refraction; the result will be the index of refraction.

No. 85280

Diffraction Attachment

This consists of a one-inch Wallace Diffraction Grating Replica of 14,438 lines to the inch (Grade D) mounted between cover glasses, which may be attached to the disc so that it occupies a central position at right angles to the optical axis of a horizontal beam of light from a single slit. The direct image of this slit may be received upon a card or screen placed at the side of the disc. The spectra of the first order will be noted on either side of the slit image; with sufficient light the spectra of the second and higher orders may also be observed.

No. 85290

Polarized Light Attachment

Professor Hartl has arranged an attachment for the Optical Disc which enables one to show to a class of students the phenomena of polarized light with as great ease as one can show the elementary phenomena of optics.

The attachment consists of a solid metal base plate B with thumb screw notches a and b, as shown in line drawing (Fig. J). This base plate is attached to the Optical Disc by two thumb screws and carries at one end, upright posts, m and n,

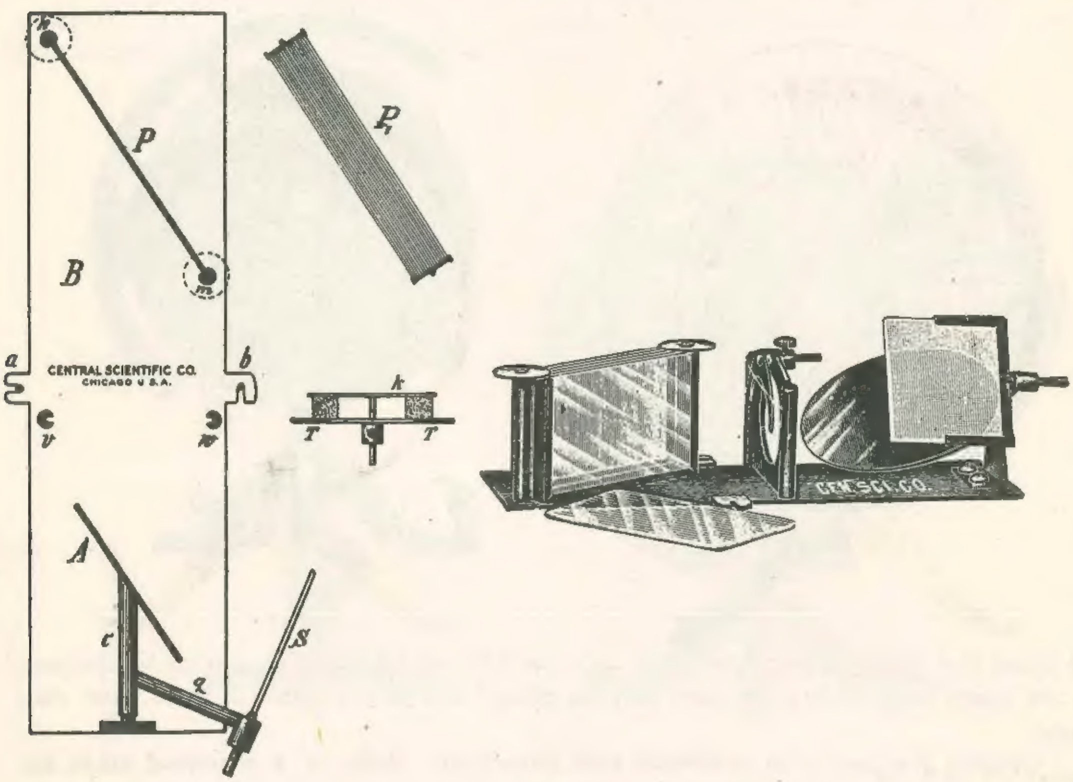

Fig. J.

which serve to hold either the single polarizing plate P or the bundle of polarizing plates (P,) in place. At the other end of the base plate is a bracket upon which the analyser (A) revolves.

The analyser consists of an elliptical plate of black glass (A) supported on a brass frame and axis (c). To the same frame is fastened the ground glass screen (S), which revolves with the analyser.

The stage (T-T) used to support objects to be examined by polarized light is held in position by posts (v) and (w).

This attachment is arranged to use on any of the Hartl Optical Discs, which are manufactured exclusively by us. It is of substantial construction and all parts are securely fastened in place to prevent possibility of accident during manipulation.

Experiments.

I.

Polarization by Reflection. Let light fall on and be reflected from the single plate glass polarizer at angle as shown in Fig. K. Place analyser in position as shown. A bright circle of light will appear on the screen. Rotate the screen and analyser on its axis 90°, and the light on the screen will almost entirely vanish (crossed position). It is at once seen that complete polarization occurs at only one angle of incidence for the least rotation of the disc in either direction (change of angle of incidence) causes the bright circle to appear upon the screen. Rotate the analyser 90° further (180° in all) and the circle of light will regain its full intensity.

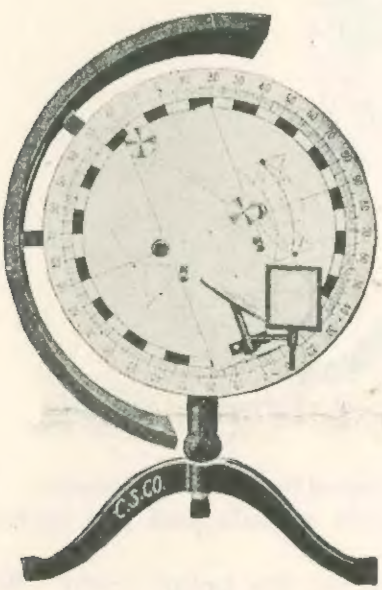

Fig. K.

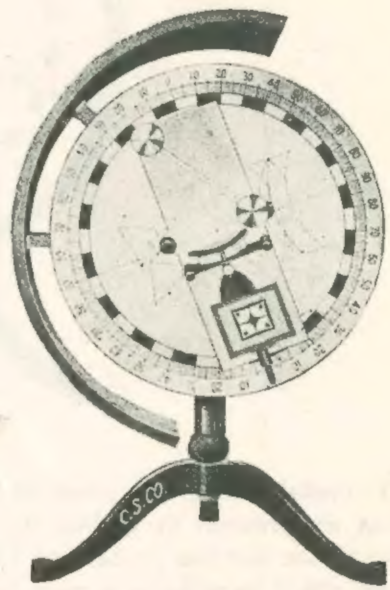

Fig. L.

II.

Polarization by Transmission. Substitute the bundle of glass plates for the single piece of plate glass. Leave all other parts in position as in experiment I. Turn the Optical Disc so that light emerges from the bundle (same arrangement as Fig M.) Polarization effects, bright and crossed, will be secured at right angles from those in experiment I.

III.

Interference of Polarized Light. With the attachment arranged for polarization by either reflection or transmission, a stage [Fig. I (T-T)] is used to hold specimens between the polarizer and the analyser. Unannealed glass blocks, (Fig. L square specimen), selenite films, mica films or torn mica edges placed on the stage will exhibit the beautiful color effects bright enough to be visible to a large number at once. The color pattern made by a plate consisting of three sheets of gypsum, arranged in the form of a butterfly, is shown in Fig. M.

IV.

Polarization of small crystals

In order to show the interference figures produced by optically uniaxial and biaxial crystals in *convergent* polarized light, arrange apparatus as shown in Fig. L and place on the stage with the clips down the metal slide holder carrying a condensing lens. Under the clips slip the crystal specimen to be examined (e. g. Sodium or Potassium Nitrate). The uniaxial crystal will give a series of concentric circles crossed by a black cross, while the

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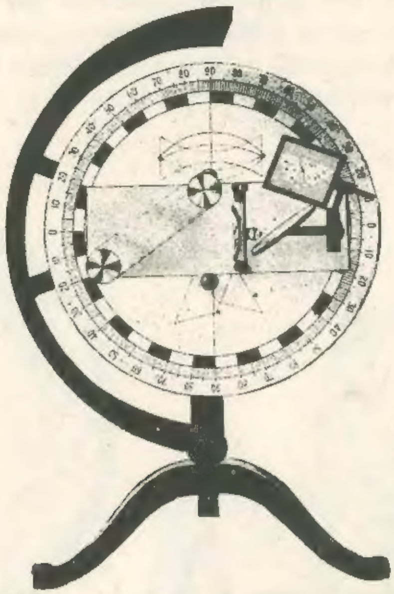

Fig. M.

biaxial crystal will give a series of lemniscates crossed by black hyperbolae. For this last experiment it is best to allow the pupils to walk past the apparatus in order to see the fine pattern on the screen.

The other experiments may be seen clear across the lecture room. When sunlight is used the room need not be darkened, for the experiments may be seen if only the ordinary window shades are pulled down. This leaves the room light enough for the pupils to see arrangement of the apparatus and the position of the analyser, all the time.

V.

Compressed Annealed Glass

Ordinary glass does not have the power of double refraction. It acquires this property if its elasticity becomes more modified in one direction than another. This can be shown by means of a Compressing Clamp and a block of annealed (common) glass. Place the compressor with block of annealed glass on the stage with other parts arranged as in Fig. L. The annealed glass when under pressure will exhibit the same color effects as the unannealed (chilled) glass *Do not compress unannealed glass blocks.*

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